Annals of Clinical and Analytical Medicine
Original Research

Virtual reality efficiency for language recovery and quality of life in Wernicke's aphasia: A randomized controlled clinical trial

VR efficiency for speech and language therapy

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Abstract
Aim: Studies on the treatments and their effectiveness in Wernicke's Aphasia are quite limited. The development of technology and the use of virtual reality implementations in rehabilitation processes increase the importance of studies reporting the effectiveness of the treatment in this regard. The aim of the study was to show the effectiveness of Virtual Reality-Assisted Language Treatment (VR-Assisted SLT) implementations in post-stroke Wernicke's Aphasia.
Material and Methods: In this context, 30 people were included in this double-blind study that had a complete experimental design and consisted of SLT, Control Group and VR-Assisted SLT who underwent the VR-Assisted treatment process by receiving the NeuroVR 2.0 open source software as a model. Ten participants were assigned for each group. Those receiving treatments received 5 sessions (minimum 45 minutes) weekly for 4 weeks. ALAT and SAQOL-39 were applied as pre-test, post-test, and follow-up tests.
Results: Naming and auditory comprehension scores were found to increase significantly over time, especially in the VR-Assisted SLT Group. Although similar increases were detected in the quality of life scores in the SLT and VR-Assisted SLT Groups, the VR-Assisted SLT Group had higher scores on physical and psychosocial subscales of the quality of life than the Control Group ($p<0.05$).
Discussion: VR-Assisted SLT applications can enhance language and quality of life scores by providing realistic experiences.

Keywords
Virtual Reality, Rehabilitation, Wernicke's Aphasia, Treatment

DOI: 10.4328/ACAM.21975 Received: 2023-09-13 Accepted: 2023-10-13 Published Online: 2023-10-14 Printed: 2023-10-15 Ann Clin Anal Med 2023;14(Suppl 3):S406-410
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This study was approved by the Clinical Research Ethics Committee of Bahçeşehir University (Date: 2023-07-19, No: 2023-14/03)

Introduction

Wernicke's Aphasia (WA), which results from damage to the left posterior temporal cortex, was described by Carl Wernicke [1] in 1874. WA is characterized by three main diagnostic criteria (i.e., impairment in auditory comprehension, impairment in repetition, and fluent speech) [2].

Most aphasic patients show some degree of spontaneous recovery, especially during the first 2-3 months after the onset of stroke. However, studies show that more significant improvement is possible when an intervention is provided, even in chronically ill patients. Aphasia, its effects and consequences for individuals and their families show the importance of planning effective treatment modalities [3]. Speech and Language Treatment (SLT) are used widely as treatment modalities for Aphasia [4]. However, trials on WA treatment have reported little success with Traditional Treatment Modalities [5].

After the development of digital technology, Virtual Reality (VR) is now used as an alternative way of intervention by adding useful components to existing treatment strategies. The development of VR implementations for aphasia rehabilitation is still in the early stages. It was also noted that there were significant acquisitions in different psychological dimensions (self-esteem, emotions, and mood) in the VR group after the intervention [6]. These characteristics show that VR has real potential to make it an ideal means of improving language function.

In line with previous literature [7], which suggests that speech-language treatment must improve functional communication in ecological contexts, the researchers hypothesized that speech-language treatment combined with VR would be effective in WA. We also believe that treatment will generalize to improved communication effectiveness and quality of life. Here, the main target is to facilitate patients' successful participation in real conversation settings by increasing communicative confidence and empowering WA patients to improve their quality of life.

Material and Methods

Participants

All patients were recruited from the Neurology Departments of various hospitals in Istanbul. The preliminary language evaluations were performed for those who wanted to participate in the study voluntarily by an independent speech-language pathologist who was blinded to the study. Inclusion criteria were speaking Turkish fluently, not having used psychotropic medication in the last month, being literate, being right-handed before the disease, having a single left-handed injury at least six months before the study, being diagnosed with Aphasia because of hemispheric paralysis, having no visual impairment (self-report), no hearing loss (screened by pure tone audiometry), and having a cut-off score of 31+ for auditory comprehension according to the Aphasia Language Evaluations Test (Aphasia severity for auditory comprehension defined at least "moderate"). Patients were randomized into three groups (VR-Assisted SLT 1, SLT 2, and Control Group (CG) by using a computer-generated randomization block. The demographic data of 30 people who completed the study are presented in Table 1.

The One-Way ANOVA comparisons were made and no significant differences were detected between the groups for age, education level, and time after stroke.

Treatment and Devices

The VR scenarios were created by using the Quest 2 Oculus 256 GB headset. Different virtual scenarios were projected in VR that the patient could explore. These scenarios were created by the authors of the study on the NeuroVR 2.0 open-source software (http://www.neurovr2.org). This software allows therapist intervention. A speech-language pathologist participated in the VR sessions for the interactive medium by using the AMBEO 360 VR Microphone. Also, a whiteboard was included in the scenarios for the therapist to provide written cues when needed.

Treatment targets were set in increasing difficulty, starting with the simplest one. Each virtual scenario contained the same number of cognitive exercises that trained different functions. To support auditory comprehension and naming, instructions e.g., "Go to the cash register", "Read the name tag", and "Say the food made from flour" were given by the therapist in VR. Tips were given to participants when necessary (in the form of directing the participant to a certain topic or presenting the instructions visually and in writing). Right at some steps, stimuli were given to patients along with distractors. For example, distractors ("mercimek-mevicek" as phonological distractors or "ekmek-pasta" as semantic distractors both voiced by the therapist with headphones and repeated by the patients, and appeared on the screen in writing. The patient was also asked to indicate the correct one (it was expected that this would be advantage for the patient, considering that reading comprehension is better preserved compared to auditory comprehension). Following this, the participants were asked to read the sentences aloud, expand a sentence with the Wh- question prompts, and make semantic judgments on the SVO sentences read aloud by SLT by using the same verb. A screenshot of one of the VR applications for the restaurant theme is shown in Figure 1.

Procedure

A total of 30 participants were assigned randomly to one of three treatment groups. The participants completed twenty-four sessions for each intensive language treatment (4 weeks X 5 days), and each treatment lasted approximately 45 minutes with short breaks. The same scenarios and the same treatment targets were followed in the treatments. However, VR scenarios were not used in traditional SLT, and the treatment was followed with printed materials. Follow-up tests were repeated 15 days after the end of the applications.

Evaluation Tools

Language, communication skills, and quality of life were tested with standardized test batteries at pre-, post-treatment, and follow-up stages to evaluate the effects of the two treatment modalities (VR-Assisted SLT and traditional SLT). The Aphasia Language Evaluations Test (ALAT) was used for language evaluations. ALAT was developed to determine the performance of individuals with brain damage in all language domains, to diagnose aphasia, and to select appropriate treatment targets [8]. It has eight sub-dimensions, but only two of them were used for the study (auditory comprehension (33 items, a = 0.97), and naming (22 items, a = .99). The Stroke and Aphasia Quality of Life Scale (SAQOL-39), which evaluates the quality of life from the patient's perspective, was used in the study [9]. The scale collects data in four areas of the patient's quality of life (physical, energy, psychosocial, and communication sub-areas).

Statistical Analysis

The results were expressed as mean (Standard Deviation) (SD). All statistical analyses were performed by using the SPSS version 23 for Windows (Statistical Package for Social Sciences, SPSS Inc.), and p < .05 was considered statistically significant. All data were evaluated with the Kolmogorov-Smirnov Test in case of normal distribution. The One-Way Anova test was used to determine possible differences between age, mean time since stroke (months), and language evaluation tests in the groups.

The variation of language evaluation and quality of life scores were evaluated at three different times, mixed-pattern analysis of variance (3 (group) x 3 (time)), analyzing the overall data, and separating data of each group by writing a syntax code. In cases where sphericity was not met, the Greenhouse-Geisser Correction was used. Also, Bonferroni Post-Hoc Modalities were used for multiple comparisons.

Ethical Approval

Ethical approval for the study was obtained from the Clinical Research Ethics Committee of Bahçeşehir University (2023-07-19, Decision N. 2023-14/03).

Results

The intragroup and intergroup comparisons of the 2 sub-areas of the ALAT were performed between the groups before, after, and after the application procedure. The scores on naming, which is the sub-field of the Aphasia Language Evaluations Test, are shown in Figure 2. The Auditory Comprehension Score is shown in Figure 3. The intra-group and inter-group comparisons are shown in these figures.

In group comparisons for the Naming Score, Mix ANOVA showed a significant effect of time in the VR-Assisted SLT Group (F(2.26)=30.414, p=0.00, np2= 0.701). According to post-hoc analysis, follow-up test scores (mean=35.500, p= 8.631) stemmed from significantly higher scores than pre-test (mean=19.300, p= 1.567) and post-test (mean= 20.80, p= 6.160). Also, scores in the CG showed significant differences

Table 1. Demographic characteristics of Participants

		VR-Assisted SLT (n=10)	SLT (n=10)	Control (n=10)	Group Comparison
Sex	Female	6	6	6	
	Male	4	4	4	
Age		60.4 (5.39)	61.4 (4.74)	59.2 (3.88)	F=0.565 p=0.575
Level of Education	Elementary	1	2	0	
	Middle	0	1	5	
	Secondary	5	4	1	
	University	4	3	4	
Mean time since stroke (months)		10.3 (1.05)	10.4 (1.34)	10.0 (1.05)	F=0.321 p=0.728
ALAT-Pre-test	Auditory Comprehension	34 (1.49)	34.6 (1.50)	34.5 (1.50)	F=0.458 p=0.637
	Naming	19.3 (1.56)	17.8 (3.29)	17.3 (3.52)	F=1.262 p=0.299

Figure 1. Screenshot of one of the VR applications for the restaurant theme.

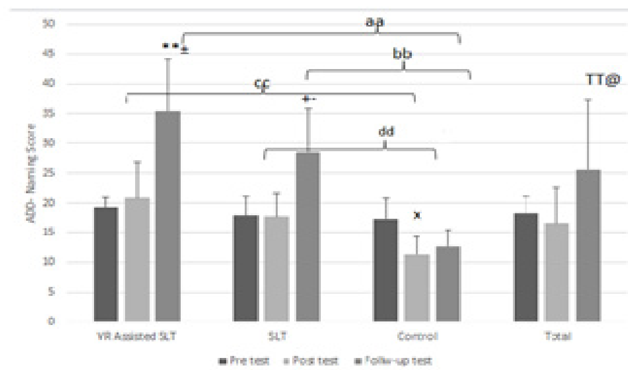

Figure 2. Significantly different from the VR-Assisted SLT pre-test, ±: VR-Assisted SLT significantly different from posttest intragroup; +: Significantly different from pretest for the SLT Group; -: Significantly different from posttest for SLT Group; x: Significantly different from pretest for Control Group; TT: Total score is significantly different from the pre-test; @: Total score significantly different from post-test; aa for significant differences between the groups; significant difference between VR-Assisted SLT and Control Group for follow-up test; bb: significant difference between SLT and Control Group for follow-up test; cc: Significant difference between VR-Assisted SLT and Control groups for post-test; dd: Significant difference between SLT and Control Group for post-test.

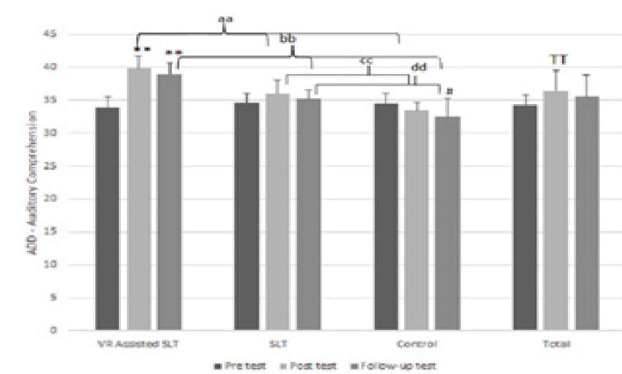

Figure 3. Significantly different from the pre-test in the VR-Assisted SLT Group, #: Significant difference from the pre-test in the Control group; TT: Significant difference from pre-test as Total Scores; aa for significant differences between groups: VR-Assisted SLT for post-test significantly different from group; bb: Significant difference from VR-Assisted SLT Group for follow-up test; cc: Significantly different from the SLT Group for post-test; dd: Significant difference from SLT Group for follow-up test.

Table 2.SAQOL-39 Scores

	Group	Pre-test Mean (SD)	Post-test Mean (SD)	Follow-up test Mean (SD)	F	(df1, df2)	p-Value	Effect n2	1-β
SAQOL-39 Psychosocial	VR-Assisted SLT	35.2 (4.960)	39.4 (9.100)	41.9 (13.500)A	3.642	(2, 26)	0.042	0.219	0.620
	SLT	37.3 (9.860)	38.8 (9.510)	39.12 (9.320)	0.322	(2, 26)	0.720	0.024	0.090
	Control	33.7 (6.610)	28.8 (7.850)**++A	30.2 (9.350)	3.178	(2, 26)	0.052	0.196	0.550
		p=0.560	F=4.520 p=0.0200 n2=0.251 1-β=0.722	p=0.600					
SAQOL-39	VR-Assisted SLT	13.6 (2.630)	13.8 (3.910)	14.2 (3.520)	0.055	(2, 26)	0.960	0.000	0.057
	SLT	14.1 (3.380)	14.0 (4.520)	13.5 (5.140)	0.065	(2, 26)	0.930	0.000	0.059
	Control	13.3 (4.080)	11.6 (4.030)	12.9 (5.100)	0.840	(2, 26)	0.440	0.060	0.178
		p=0.870	p=0.370	p=0.820					
SAQOL-39 Communication	VR-Assisted SLT	16.7 (3.160)	27.3 (5.220)A	28.7 (3.30)A	80.260	(2, 26)	0.000	0.861	1.000
	SLT	18.2 (3.350)	28.9 (3.280)A	26.9 (2.460)A	62.555	(2, 26)	0.000	0.828	1.000
	Control	14.8 (4.230)	13.4 (3.470)**++	13.7 (3.650)**++	1.051	(2, 26)	0.360	0.075	0.214
		p=0.120	F=43.46 p=0.000 n2=0.76 1-β= 1.000	F=66.31 p=0.000 n2=0.831 1-β=1.000					
SAQOL-39 Physical	VR-Assisted SLT	53.5 (12.530)	66.5 (16.000)A	66.9 (16.410)A	36.420	(2, 26)	0.040	0.219	0.620
	SLT	48.8 (8.950)	62.7 (19.600)	61.9 (22.190)**	0.322	(2, 26)	0.720	0.024	0.096
	Control	51.9 (14.640)	51.8 (16.360)**	57.6 (19.650)**	31.780	(2, 26)	0.051	0.196	0.558
		p=0.20	F=23.358 p=0.000 n2=0.63 1-β=1.000	F=26.590 p=0.000 n2=0.663 1-β=1.000					

A: Significantly different from the pre-test in the group, B: Significantly different from the post-test in the group, **: Significantly different from the VR group between groups, ++: Significantly different from the SLT Group between groups.

over time. Follow-up test scores (mean= 19.600, p= 5.966) were significantly higher than the pre-test scores (mean= 17.300, p= 3.529) and than post-test scores (mean= 17.300, p= 3.368). The post-test scores (mean= 11.300, p= 2.983) were significantly lower than the pre-test scores in the CG (mean= 14.033, p=4.278).

The Mix ANOVA was used for intergroup comparisons of Naming Scores, post-test (F(2.27)= 11.320, p= 0.00, np 2= 0.456), and follow-up test scores (F(2.27)= 30.480, p=0.00, np2= 0.693), which showed that there was a significant difference. According to post-hoc analysis, post-test scores occurred because of significantly higher scores of the VR-Assisted SLT Group (mean= 20.800, p= 6.160) than the CG (mean= 11.300, SD= 2.983). Also, post-test scores differed between the SLT Group (mean= 17.700, p= 3.917) and the CG (mean= 11.300, SD= 2.983).

The significant difference between the follow-up test scores occurred because the CG scores (mean= 12.700, p= 2.750) were significantly lower than the VR-Assisted SLT Group scores (mean= 35.50, SD= 8.631) in the post-hoc analyses. Also, a significant difference was detected between SLT Group scores (mean= 28.60, p= 7.244) and CG scores

Mix ANOVA showed a significant effect of time on auditory comprehension in the VR-Assisted SLT Group (F(2.26)= 43.015, p= 0.00, np2= 0.768). According to post-hoc analyses, a significant difference was detected in auditory comprehension scores over time in the VR-Assisted SLT Group, post-test (mean= 39.800, p= 1.932) and follow-up tests (mean= 39.00, SD= 1.633) than pre-test (mean= 34.00, SD= 1.490) was significantly higher. It was also found that there was a significant effect of time on recurrence in the CG (F(2.26)= 3.593, p= 0.00, np2= 0.042).

Significant differences were detected between the groups regarding auditory comprehension. A significant difference was detected between post-test scores (F(2.27)= 30.841 p=0.000, np2= 0.696) and follow-up test scores (F(2.27)= 25.233, p=0.000, np2= 0.651).

Significant differences were detected between the groups in auditory comprehension. According to the post-hoc analysis, post-test scores were found to be significantly higher than those of the VR-Assisted SLT Group (mean= 39.800, p= 1.932), SLT (mean= 36.000, p= 2.160), and CG (mean= 33.500, p= 1.178). This occurred because of the significantly higher scores. Post-test scores also differed significantly between the SLT (mean= 36.000, p= 2.160) and CG (mean= 33.500, p= 1.178).

According to post-hoc analyses, the difference between the groups in follow-up test scores, which were significantly higher than that of the VR-Assisted SLT Group (mean= 39.000, p= 1.633), SLT (mean= 35.200, p= 1.398) and CG (mean= 32.500, p= 2.838). This occurred because of the high scores. Follow-up test scores also differed significantly between the SLT (mean=35.200, p= 1.398) and CG (mean=32.500, p= 2.838).

Mix ANOVA analyses regarding SAQOL-39-Scale scores are shown in Table 2.

Discussion

The study investigated the effects of virtual reality and traditional speech treatment combined with a speech treatment approach to improve the language characteristics and the quality of life of people with chronic WA after stroke.

The study showed that significant improvements could be achieved in different areas of language in groups that received treatment. Previous studies showed that Chronic Aphasia also developed in similar aspects [10]. A significant difference was detected over time in both groups, especially in naming scores. Expressions that were not understandable or meaningful were not added to the scores, which can be explained by the strengthening of lexical-semantic connections [11]. The researchers did not expect such a significant increase in the findings regarding naming, which is one of the subtests of ALAT, in the groups receiving treatment, especially in follow-up tests. For this reason, these results replicate other findings showing that language development can be achieved through intensive treatment, even in chronic Aphasia [12]. The scores related to naming decreased over time in the CG. When naming scores were evaluated, the decrease may be associated with the participant's difficulty in auditory comprehension because all WH questions are given verbally in ALAT. Also, the increase in time after the diagnosis and the absence of any intervention explain the decrease in scores.

Although the groups had the same treatment targets, content, and difficulty levels, the greatest improvement was achieved in the VR-Assisted SLT Group (auditory comprehension and naming). It has been suggested that it allows treatments and might support the recovery of patients with Aphasia with greater stimulation of neuroplasticity processes [13]. Also, it may have enabled patients to focus more on speech treatment because the VR system almost completely blocks interference from the outside world (except for verbal interventions from the therapist) and virtual reality might also help reduce feelings of embarrassment that might accompany communication failure in real settings. For this reason, it encourages the practice of difficult communication exchanges and can promote the generalization of therapeutic abilities from the clinic to real-world settings [13,14].

Aphasia has adverse effects on a patient's psychological health, independence, quality of life, and mood, negatively affecting daily communication and social participation [15]. Self-reported data on the SAQOL-39 test used in the study showed that the VR group had positive improvements in physical, psychosocial, and communication areas after the treatment. These findings are particularly important because the VR intervention showed that although language and speech intervention was planned, it also improved the emotional state of the patients. Studies confirm the positive effects of language-oriented treatment on people's quality of life [10].

One of the strengths of the present study might be that it showed that treatment targets were increasingly maintained even one month after the application, especially in the VR-Assisted Group. Also, the study included people receiving both VR-Assisted Treatment and Traditional Treatment. The CG that received no intervention was also employed to determine whether the treatment was effective.

Limitation

The main limitation of the study was the small sample size, which might not be sufficient to prove the actual effectiveness of the advanced virtual reality-assisted speech treatment in the WA population. However, the study managed to demonstrate the feasibility and potential effectiveness of VR in the treatment of Aphasia.

Conclusion

In conclusion, the study showed that VR can affect WA rehabilitation positively by enhancing communication, naming and auditory comprehension. More extensive and multicenter studies are needed to confirm these promising findings.

Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Funding: *None*

Conflict of Interest
The authors declare that there is no conflict of interest.

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How to cite this article:
İbrahim Can Yaşa, Gözde Malkoç. Virtual reality efficiency for language recovery and quality of life in Wernicke's aphasia: A randomized controlled clinical trial. Ann Clin Anal Med 2023;14(Suppl 3):S406-410

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